International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249–6890; ISSN (E): 2249–8001
Vol. 10, Issue 2, Apr 2020, 727–736
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OPTIMIZING MACHINING PARAMETERS OF EDM FOR TITANIUM ALLOY [Ti 6al-4v Eli] BY TAGUCHI METHOD AND PROMETHEE METHOD- AN EXPLORATORY INVESTIGATION

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ABSTRACT

To determine optimal or near optimal cutting conditions in various kinds of metal cutting process optimization problems, it incorporates the use of one or more of the existing modelling and optimization techniques, making the framework a unified and effective mean. The Electrical Discharge Machining (EDM) is one of the most well-known and most acknowledged non-conventional machining process utilized. The work-piece material chose in this test is Titanium Grade 23 Alloy [Ti 6AL-4V ELI] considering its wide utilization in modern application. The high quality and solidness of Titanium Grade 23 Alloy prompts improve tractable shear and flexural properties. Variable parameters taken into account are peak current, pulse on schedule, and pulse off time and gap voltage. Based on PROMETHEE grid philosophy for four components with three degrees of each factor, L9 array was chosen. Cluster for design of experiments to be done for knowing the TWR and MRR, the impact of the variable parameters referenced above after machining qualities, for example, MRR and TWR is considered and examined. The instrument material is COPPER CADMIUM.

KEYWORDS: Electric Discharge Machining, Tool Wear Rate, Material Removal Rate, Peak Current & Flushing Pressure

Received: Feb 08 2020; **Accepted:** Feb 28, 2020; **Published:** Mar 25, 2020; **Paper Id.:** IJMPERDAPR202072

Original Article

1. INTRODUCTION

The force and pulse time factor were the most basic if there ought to emerge an event of SR, while the obligation cycle factor was not critical using any and all means. The power factor was again influential in case of TWR. The fundamental elements if there ought to emerge an event of MRR were the force taken after by obligation cycle and the pulse time as examined by Puertas et al. [1]. Kumar et al. [2] explored the ideal machining parameters for mix threw utilizing 5% (wt) B4C particles of 50 micron size in Al 6061 metal framework utilizing Taguchi strategy and broke down the test results utilizing ANOVA system. He presume that current is most noteworthy factor influencing MRR and surface harshness while the terminal material is liable for TWR. Lin et. al. [3] utilized the L8 symmetrical exhibit of Taguchi method to streamline the various parameters of machining like peak current, no load voltage, pulse term influencing the MRR and TWR. Mahapatraet. al. [4] used Taguchi's parameter design to recognize imperative machining parameters: release current, pulse term, pulse repeat, wire speed, wire pressure and dielectric stream affecting the execution proportions of WEDM. The association between control components and responses like Metal Ejection Rate (MRR) Surface Completion (SF) and cutting width (kerf) were set up by techniques for non-straight backslide examination, achieving a generous scientific model. Bhattacharya et al. [5] watched that peak current and pulse on time basically affected particular criteria of surface decency, for instance,

thickness of cracks, surface obnoxiousness and white layer thickness. Scott et al [6] chose MRR and surface completion quality as a proportion of execution of the model taken. He utilized two techniques one is unequivocal list and other depends on unique programming. Ohdar et al. [7] utilized mellow steel material as work-piece and copper as apparatus for machining with negative extremity and concentrate the impacts of peak current, pulse off time, pulse on time and blazing pressure on MRR and TWR and he got the ideal outcome for MRR at top current 12 ampere, pulse on time 15µs, pulse off time 3µs and flushing pressure 0.3 kg/cm2 and at top current 14amp, pulse on time 5µs, pulse off time 7µs and flushing pressure 0.3 kg/cm2 the instrument wear rate (TWR) lessens fundamentally. Tomadi et al. [8] explore that for MRR the most convincing was pulse on time took after by voltage, current stream and pulse off time. Finally in case of TWR the crucial factor was pulse off time took after by top current. B. S. Reddy et. al. [9] used mixed factorial blueprint of preliminaries and diverse relapse assessment frameworks had been used to achieve the desired results. Gopalakannan et al. [10] studied the consolidated Taguchi technique and grey relational examination to improve the numerous exhibition attributes of MRR, EWR and SR in EDM of aluminum hybrid metal matrix composite and found that optimum results at pulse current at 32Amps, Voltage at 60 Volts and Pulse on time at 2µs. Lin et al.[11] utilize grey relational investigation dependent on a symmetrical exhibit and fuzzy based Taguchi technique for upgrading the multi-reaction process is accounted for. Both the grey relational investigation strategy without utilizing the S/N proportion and fuzzy rationale examination are utilized in a symmetrical cluster table in completing analyses for fathoming the various reactions in the Electrical Release Machining (EDM) process. Test results have indicated that the two methodologies can enhance the machining parameters (pulse on time, duty factor, and discharge current) with contemplations of the different reactions (anode wear proportion, material expulsion rate, and surface harshness) adequately. Chandramouli et al. [12] studied that the MRR is increasing with increment in current and it decreases initially with pulse on time but later it increases, while the TWR increases linearly with current and pulse off time but decreases in relation with pulse on time also. The third parameter he considered is surface roughness which increases with increase in current and pulse on time and decreases in relation with increasing pulse of time.

2. EXPERIMENTAL DETAILS

2.1 Experimental Setup

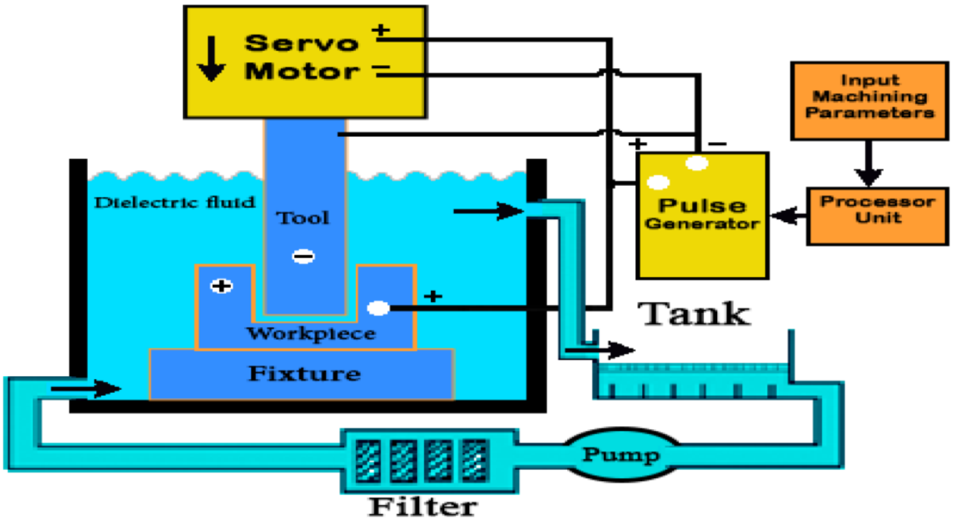

Figure 1: Concept of the EDM.

Figure 1 shows the mechanical arrangement and electrical arrangement and electrical circuit for electro release machining.

Both tool and work-piece are submerged in a dielectric fluid. Kerosene oil/EDM oil is very essential sort of liquid dielectric but vaporous dielectrics can moreover be used in specific cases. The device goes about as cathode and work-piece goes about as anode. Voltage in type of a flash release through the hole, when adequate enough in a period interim of 10 micro scale seconds. In light of heat the positive particles and electrons produce a conductive release channel. It is actually now when the sparkle bounces causing crashes among particles and electrons and making a channel of plasma. The moment flash happens enough pressure is created among work and tool as a result of which a high temperature is come to and at such high pressure and temperature some bit of metal is condense and crumbled. Table 1 shows the subtleties of the EDM machine used in the midst of the experimentation.

Table 1: EDM Specification

Designations	Value
Model	ZNC 50 A
Maximum Work Piece Size	800*500*325(mm*mm*mm)
Resolution	0.0005 mm
Peak Current Reach	Upto 20 ampere
Gap Voltage Reach	10 to 120 volts
Pulse Duration Reach	0.3 to 550 μ-seconds
Connected Load	10 KVA
Heat Generation	12 K-Cal/Hour
Temperature to be maintained	20+/- 2*C
X, Y and Z axis travel	400,300 and 300mm respectively
Dielectric solution (DS)	kerosene oil
Thermal conductivity for DS	0.158 W/m-K
Specific Heat Capacity for DS	2.2 J/g-K
Dynamic Viscosity for DS	1.56 g/m-sec

The work piece material used as a piece of this examination is Titanium Grade-23 composite which has a high caliber to strength to weight extent. Table 2 represents the properties of Titanium Grade-23 amalgam are according to the accompanying.

Table 2: Specifications of Work Piece Material

Properties/ Specification	Value
Atomic Volume	0.013 m^3/kmol
Density	4.47 Mg/m^3
Hardness, Rockwell C	35
Elastic Modulus	113.8 GPa
Yield strength	790 MPa
Melting Point	1935K
Thermal Conductivity	6.70 W/mK
Size of Sample	160mm length and 15mm diameter

Figure 2: Tool (Cu-Cd) Material.

The apparatus for machining used as a piece of the assessment is of COPPER-CADMIUM shown in Figure 2 which is by and large being used as a piece of organizations for tooling of EDM. The properties of copper cadmium are according to the accompanying table 3:

Table 3: Properties of Tool Material

Properties/ Specification	Value
Thermal Conductivity	389 $W/m^0 K$
Melting Point	1100 ^0C
Electrical Resistivity	1.64 ohm-cm
Specific Heat Capacity	0.395 J/gm-^0C
Size of Sample	12 mm (ø) * 70mm

2.2 Design of Experiment

Based on literature review, the accompanying parameters which have sensible impact on tool wear during EDM machining process are.

- Peak current (I_p)
- Pulse on time (T_{on})
- Gap voltage (V_g)
- Pulse off time (T_{off})

2.2.1 Level Values Selection

The Taguchi's procedure utilizes symmetrical bunches from plan of tests speculation to ponder a broad number of variables with reasonable amount of examinations. Using symmetrical groups basically lessens the number of preliminary structures to be considered. Orthogonal array for level values selections is shown in Table 4.

Table 4: Orthogonal Array

Experiment No.	Factor1	Factor2	Factor3	Factor 4
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	2	1	3
5	2	3	2	1
6	2	1	3	2
7	3	3	1	2
8	3	1	2	3
9	3	2	3	1

Table 5 represents the four parameters, each at three levels. This is known as a L9 table, with the 9 indicating the nine lines, arrangements or models to be attempted. In view of TAGUCHI Method, for Four parameters with Three Levels of each parameter, the L9 ARRAY for DOE of the examinations to be finished for knowing the MRR and TWR.

Table 5: Different Level Estimations of Chosen Factors

Factor Symbol	Process Parameters	Units	Level 1	Level 2	Level 3
A	Peak Current (I_p)	Ampere	12	16	20
B	Pulse On Time (T_{on})	Micro-seconds	60	80	100
C	Pulse off Time (T_{off})	Micro-seconds	6	8	10
D	Gap Voltage	Volts	50	70	90

2.2.2 L9 Array Table for Experiment

By putting the chose level estimations of different chose parameters from Table {5}, following L9 cluster is generated as shown in Table 6 for genuine test.

Table 6: L9 Array Table for Actual Experiment

Experiment No.	Peak Current (I_p)	Pulse On Time (T_{on})	Pulse Off Time (T_{off})	Gap Voltage (V)
1	12	60	6	50
2	12	80	8	70
3	12	100	10	90
4	16	60	8	90
5	16	80	10	50
6	16	100	6	70
7	20	60	10	70
8	20	80	6	90
9	20	100	8	50

The 9-tests were played out in the premise of the above table on the different blend of variables as appeared in table {6}. Prior and later of each test readings are taken for investigation of MRR and TWR.

3 EXPERIMENTAL PROCEDURE AND RECORDS

A progression of investigations were performed on a die- sinking EDM. The work piece of size 160mm length and 15mm diameter and tool material of length 70mm and diameter 12mm was utilized. The round cathode is favoured over different states of terminals, gives higher MRR and lower TWR. Commercial grade kerosene oil was utilized as the dielectric liquid and motivation fly flushing framework was utilized to flush away the dissolved materials from the sparking zone. The machining is accomplished for 10 minutes for all examinations. The material expulsion rate and tool wear rate have been determined by deciding the weight contrast of the work piece and tool material when the machining utilizing an advanced gauging size of 0.001 gram accuracy. The experimental data obtained for material removal from work piece and tool material in different experiments performed are shown in table 7 and table 8 respectively.

Table 7: Observation Table for MRR

Experiment No.	Wt. before Machining (g)	Wt. after Machining (g)	Time (min)	Material Removed (g)
1	32.3306	32.2881	10	0.0425
2	32.2881	32.2479	10	0.0402
3	32.2479	32.2061	10	0.0418
4	32.2061	32.1652	10	0.0409
5	32.1652	32.1079	10	0.0573
6	32.1079	32.0557	10	0.0522
7	32.0557	31.9944	10	0.06131
8	31.9944	31.9393	10	0.05515
9	**31.9393**	**31.8682**	10	**0.07102**

Table 8: Observation Table for TWR

Experiment No.	Wt. before machining (g)	Wt. after machining (g)	Time (min)	Material Removed (g)
1	28.73548	28.7071	10	0.02839
2	28.7071	28.69559	10	0.0115
3	**28.6956**	**28.687**	**10**	**0.0086**

4	28.687	28.6707	10	0.0163
5	28.671	28.6378	10	0.0332
6	28.6378	28.6281	10	0.0097
7	28.6281	28.5649	10	0.06312
8	28.5649	28.53754	10	0.02736
9	28.53754	28.50503	10	0.03251

4. RESULTS AND DISCUSSIONS

The machining execution criteria chose for this investigation depended on execution qualities, for example, material removal rate (MRR), tool wear rate (TWR).

$$MRR = (W_{wb}-W_{wa})/t \tag{1}$$

Where, W_{wb} and W_{wa} are weight of work piece before and after machining respectively and t is time of machining.

$$TWR = (W_{tb}-W_{ta})/t \tag{2}$$

Where, W_{tb} and W_{ta} are weight of tool before and after machining respectively and t is time of machining.

The Material Removal Rate (MRR) and Tool Wear Rate (TWR) is calculated for the whole series of experiments on the basis of weight difference of work piece material and tool material respectively with help of above showed equations and calculated MRR and TWR in different experiments performed is shown in table 9 shown here.

Table 9: Results of MRR and TWR

Experiment No.	Peak Current (I_p)	Pulse On Time (T_{on})	Pulse Off Time (T_{off})	Gap Voltage (V)	MRR (g/min)	TWR (g/min)
1	12	60	6	50	0.00425	0.002839
2	12	80	8	70	0.00402	0.00115
3	12	100	10	90	0.00418	**0.00086**
4	16	60	8	90	0.00409	0.00163
5	16	80	10	50	0.00573	0.00332
6	16	100	6	70	0.00522	0.00097
7	20	60	10	70	0.006131	0.006312
8	20	80	6	90	0.005515	0.002736
9	20	100	8	50	**0.007102**	0.003251

From table {9}, it can be seen that maximum MRR is obtained in experiment number 9 and minimum TWR is obtained in experiment number 3.

4.1 Decision Making Technique

To obtain a normalised result, a decision making procedures or technique is used to validate the final result. The technique which is applied for results validation in this article is PROMETHEE Method, it was exhibited by Brans in 1984 and has a spot with the class of outranking systems. Like all outranking procedures, PROMETHEE proceeds to a couple canny assessment of choices in each single measure with a particular ultimate objective to choose fragmentary matched relations connoting the nature of tendency of a choice a1 over choice a2. The execution of PROMETHEE requires additional sorts of information, to be explicit:

- Data on the relative noteworthiness or the loads of the criteria considered, and
- Data on the main tendency work, which he/she uses when taking a gander at the dedication of the choices to the

extent each extraordinary measure.

The system displayed for basic leadership in the assembling condition utilizing improved PROMETHEE strategy is depicted beneath:

4.1.1 Recognizing the other Options and Characteristics

Identify the selection criteria for the considered decision making problem and short list the alternatives on the basis of the identified criteria satisfying the requirements as shown in Table 10.

Table 10: Recognizing the other Options and Characteristics

Alternatives	C1 (MRR)	C2 (TWR)
1	0.00425	0.002839
2	0.00402	0.00115
3	0.00418	**0.00086**
4	0.00409	0.00163
5	0.00573	0.00332
6	0.00522	0.00097
7	0.006131	0.006312
8	0.005515	0.002736
9	**0.007102**	0.003251

4.1.2 Decision table for Metal Removal Rate (MRR) and Tool Wear Rate (TWR)

After short listing the alternatives, preparing a decision table for both MRR and TWR including the measures or values of all criteria for the short-listed alternatives as shown in table 11 and 12 for MRR and TWR respectively.

Table 11: Decision Table for Metal Removal Rate (MRR)

	1	2	3	4	5	6	7	8	9
1	_	1	1	1	0	0	0	0	0
2	0	_	0	0	0	0	0	0	0
3	0	1	_	1	0	0	0	0	0
4	0	1	0	_	0	0	0	0	0
5	1	1	1	1	_	1	0	0	0
6	1	1	1	1	0	_	0	0	0
7	1	1	1	1	1	1	_	1	0
8	1	1	1	1	1	1	0	_	0
9	1	1	1	1	1	1	1	1	_

Table 12: Decision Table for Tool Wear Rate (TWR)

	1	2	3	4	5	6	7	8	9
1	_	0	0	0	1	0	1	1	1
2	1	_	0	1	1	0	1	1	1
3	1	1	_	1	1	1	1	1	1
4	1	0	0	_	1	0	1	1	1
5	0	0	0	0	_	0	1	0	0
6	1	1	0	1	1	_	1	1	1
7	0	0	0	0	0	0	_	0	0
8	0	0	0	0	1	0	1	_	1
9	0	0	0	0	1	0	1	0	_

4.1.3 Normalized Matrix

The weights of the relative importance of the criteria may be assigned using analytic hierarchy process, to do so, one has to construct a pair-wise comparison matrix using a scale of relative importance. The geometric mean of analytic hierarchy process is used in the present work to find out the relative normalized weights of the criteria because of its simplicity. The determined weightage criteria for MRR and TWR are 0.75 and 0.25 separately and normalized matrix with determined weightage criteria is shown in table 13.

Table 13: Normalized Matrix

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**ϕ^+**
1	_	0.75	`0.75	0.75	0.25	0	0.25	0.25	0.25	3.25
2	0.25	_	0	0.25	0.25	0	0.25	0.25	0.25	1.75
3	0.25	1	_	1	0.25	0.25	0.25	0.25	0.25	3.5
4	0.25	0.75	0	_	0.25	0	0.25	0.25	0.25	2
5	0.75	0.75	0.75	0.75	_	0.75	0.25	0	0	4
6	1	1	0.75	1	0.25	_	0.25	0.25	0.25	4.75
7	0.75	0.75	0.75	0.75	0.75	0.75	_	0.75	0	5.25
8	0.75	0.75	0.75	0.75	1	0.75	0.25	_	0.25	5.25
9	0.75	0.75	0.75	0.75	1	0.75	1	0.75	_	6.5
ϕ^-	4.75	6.5	4.5	6	4	3.25	2.75	2.75	1.5	

4.1.4 Net Dominance Table

For PROMETHEE outranking relations, the leaving flow, entering flow and the net flow for an alternative belonging to a set of alternatives is defined by the following equation:-

$$\Phi\ (a) = \phi^+\ (a) - \phi^-\ (a) \tag{3}$$

Where a is the alternative or experiment number. The net dominance table for the technique applied is shown in table 14.

Table 14: Net Dominance Table for PROMETHEE Method

Experiment no.	Net dominance	Rank
1	-1.5	7
2	-4.75	9
3	-1	6
4	-4	8
5	0	5
6	1.5	4
7	2.5	3
8	2.5	2
9	**5**	**1**

It is seen that a systematic approach of modelling and determination of optimal or near optimal cutting conditions has shown an interesting potential in both product and process quality improvement of metal cutting operation, the generic framework for process parameter optimization in metal cutting operation attempts to provide a single, unified and systematic approach to determine optimal or near optimal cutting conditions in various kinds of metal cutting process optimization problems, it incorporates the use of one or more of the existing modelling and optimisation techniques, making the framework a unified and effective mean. As already shown in table {14} that the net dominance of experiment number 9 is maximum according to applied PROMETHEE method (a decision making technique) hence experiment

number 9 gives the optimum results shown in Table 15. From table {15} it can see that at peak current 20 ampere, gap voltage50 volts, pulse on time 100 micro seconds and pulse off time 8 micro seconds, optimum values of MRR and TWR are 0.007102 and 0.003251 respectively.

Table 15: Optimum Results of Experiment

Exp no.	Peak current	Gap Voltage	Pulse On time	Pulse off time	MRR	TWR
9	20	50	100	8	**0.007102**	0.003251

6. CONCLUSIONS

The perfect mix of procedure parameters are arrived by using unmistakable tactics and play out the assertion test for endorsement of the results. Taguchi is used to get that the responsibility of each parameter for upgrade of execution measures. Following ends are drawn:-

- Peak current (Ip) contribute most inside and out towards MRR and TWR took after by gap voltage, pulse on and pulse off time.
- The perfect blend of procedure parameters which give most outrageous estimation of MRR and least estimation of TWR in EDM process is gotten at test no. 9.
- The optimum values of MRR and TWR for peak current 20 ampere, gap voltage 50 volts, pulse on time 100 micro seconds and pulse off time 8 micro seconds are 0.007102 and 0.003251 respectively.

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